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HAWAII AGRICULTURAL EXPERIMENT STATION
HONOLULU, HAWAII
Under the supervision of the
UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 54

EDIBLE CANNA IN HAWAII

BY

H. L. CHUNG, Specialist in Tropical Agronomy
and
J. C. RIPPERTON, Chemist

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HAWAII AGRICULTURAL EXPERIMENT STATION, HONOLULU

[Under the supervision of the Office of Experiment Stations, United States Department of Agriculture]

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By H. L. Chung, *Specialist in Tropical Agronomy*, and J. C. Ripperton, *Chemist*

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INTRODUCTION

Edible canna (*Canna edulis*), known also as the Queensland arrowroot, Australian arrowroot, adeira (Peru), and "tous-les-mois" (West Indies), is indigenous to South America, where it is found growing in Brazil, Peru, and Trinidad.[1] In many tropical countries the tuberous roots are cooked as a vegetable, but in South America and in several of the colonies of Australia the plant is cultivated chiefly for the sake of its starch.[2]

The exact length of time edible canna has been growing in Hawaii is not known, but it is thought that the plant was introduced into the islands about the year 1898.[3] The first planting at the Agricultural Experiment Station was made December 8, 1915, from a small quantity of tubers received from Judge J. A. Matthewman, Kailua, Hawaii. A large number of the plants were afterwards distributed throughout the Territory for the purpose of utilizing the tubers for food in case of necessity during the food shortage incident to the World War. The tubers are not popular as a vegetable in Hawaii because of the length of time required to cook them. The tops, however, furnish a large amount of excellent forage for cattle and poultry, and the plant now occupies a well-established place among stock feeds.

Starch has been manufactured from edible canna for more than 50 years in Queensland, Australia, but the industry was not successfully launched in Hawaii until 1922, although the experiment

[1] Textbook of tropical agriculture, p. 283. H. A. Alford Nicholls.
[2] Tropical agriculture: A treatise on the culture, propagation, commerce, and consumption of the principal products of the vegetable kingdom, p. 344, 345. P. L. Simmonds.
[3] Hawaii Sta. Rpt. 1917, p. 51.

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station had repeatedly made experimental starch extractions to demonstrate the possibilities of the crop. Much interest is at present being manifested in the growing of edible canna for commercial starch production, and thousands of acres of the uplands, which are not suited to pineapple and sugar cane growing, have shown considerable adaptability to the crop.

BOTANICAL DESCRIPTION

Edible canna is a member of the family Cannaceæ, and is closely related to the common flowering varieties which are grown as ornamentals in many parts of the world (fig. 1). It is perennial in tropical

FIG. 1.—A field of edible canna ready for harvesting.

countries, and is propagated either by means of young shoots which are detached from the parent stool, or by underground fleshy corms, commonly called tubers or rootstocks, which are very rich in starch. The tubers vary from cylindrical to tapering and spherical to oval, ranging from 2 to 3½ inches in diameter and from 4 to 6 inches in length (fig. 2). The stems are usually stout, and are tinged with dark lavender which is rather pronounced at the base of the very young shoots. They grow in clumps averaging 12 stems each, attain a height of 4 to 8 feet, depending upon climatic and soil conditions, and blossom in 4 to 6 months in Hawaii. The flowers are bright red with narrow petals. The seed pods are usually large when normally developed, but in most cases produce no viable seed.

CLIMATIC AND SOIL REQUIREMENTS

The luxuriant growth made by edible canna in various locations of widely differing altitude in Hawaii would seem to indicate that the crop is not exacting in its climatic requirements. It thrives from sea level to an elevation of 2,700 feet near Waimea, Island of Hawaii. In short growing periods, however, the crop produces its maximum yield at an elevation of less than 1,500 feet and when the days and nights are relatively warm, the rainfall is adequate, and protection is afforded against strong winds.

As is true of other root crops, edible canna makes its best development when it is grown in a loose, loamy soil containing an abundance of humus. When the crop is grown in a clay soil, the yield is materi-

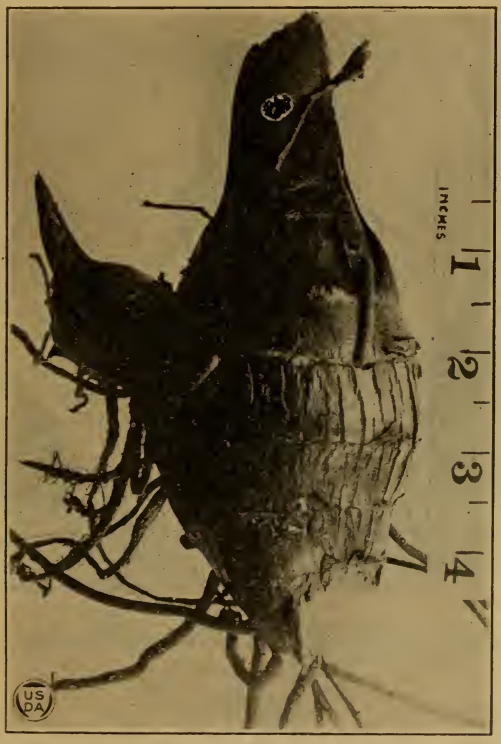

FIG. 2.—A typical edible canna corm.

ally reduced and the size of the individual tubers considerably diminished. Clayey soil renders difficult the work of harvesting and usually causes the plant to make a poor stand. Edible canna will withstand an excessive amount of moisture in the form of rainfall and irrigation, but it will not grow in soil that is not well-drained.

METHODS OF CULTURE

SELECTION OF PLANTING STOCK

Only tubers which have attained normal size and development and bear one or more healthy, unbruised buds should be selected for planting (fig. 3). As a precautionary measure against rot-producing organisms, the station dips all tubers at the time of digging in a 10 per cent solution of copper sulphate.

PREPARATION OF THE LAND

Edible canna should be planted on land that has been thoroughly plowed and cleared of weeds and débris. Loose, loamy soil should be plowed to a depth of 8 inches and then worked down with a disk harrow. Clayey soil should be given two plowings a week or more apart. Just before the second plowing is given, manure, or any form of vegetable matter, should be scattered over the soil. The physical condition of clayey soil will be greatly benefited by an application of manure or of slaked lime (at the rate of 2 tons per acre). Deep plowing, especially on clayey soils, is essential to the successful production of edible canna since it gives the roots a larger feeding area than they would otherwise have.

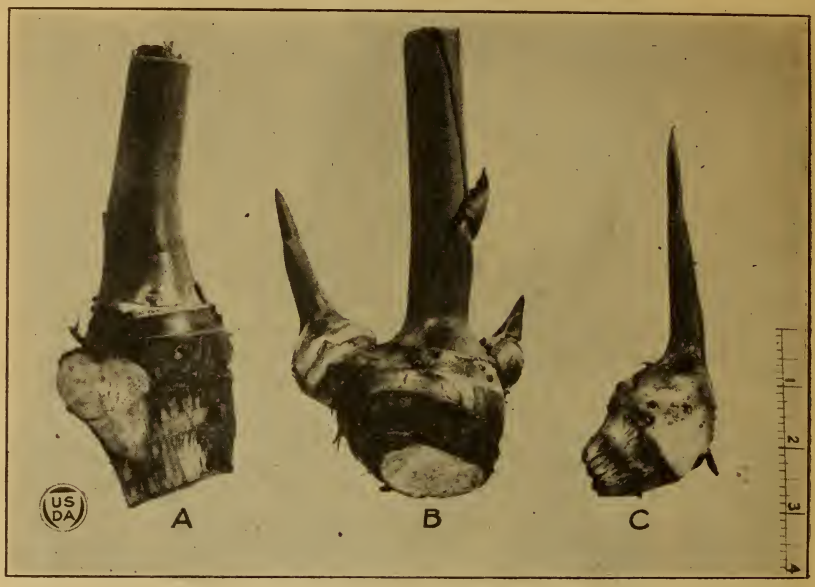

FIG. 3.—Stages of maturity in the growth of the edible canna tuber. (A) Old. An undesirable type of corm for planting. (B) Mature. A desirable seed corm for propagation. Adventitious buds insure quick growth. (C) Immature.

PLANTING

In the Hawaiian Islands, where the temperature is fairly uniform throughout the year, edible canna may be planted at any season except during a period of drought, and even then if irrigation is available. Maturing sufficiently for harvesting in eight months, the crop should occupy the ground during the eight most favorable months for growth, unless, of course, the immediately preceding or following crop is entitled to primary consideration.

In a loose, loamy type of soil, the tubers should be planted 5 inches deep at distances of 3 feet in rows that are 3 feet apart. A spacing of 3 by 3 feet will permit of planting 4,840 hills per acre, and render cross-cultivation possible while the plants are young. In a heavy type of soil, the planting distance should be increased to 4 feet each way, and the tubers planted not more than 3 inches deep. The increased distance will permit of cultivation until the

crop has grown to considerable size. The tubers should be dropped by hand into furrows that are made by an animal-drawn plow. At the station, a plank drag has been effectively used to cover the tubers to the proper depth.

CULTIVATION

Edible canna readily responds to good cultivation. As soon as the plants are 6 inches high, the ground should be cultivated with a tooth harrow which is properly adjusted to cover the width of the rows. Heavier cultivators can be used to advantage with the increased growth of the crop. Cross-cultivation thoroughly stirs the soil and enables the tubers to make good growth. Hard, compact soil causes them to become stunted. At the station, the last cultivation is usually given about 4 months after planting. From this time on, cultivation is almost impossible because of the spreading growth of the clumps of stalks. Weed growth, however, is then effectually kept down and smothered out by the luxuriant foliage which shades the ground.

FERTILIZERS

Little is known regarding the fertilizer requirements of edible canna. In a preliminary experiment conducted by the station,[4] fertilizers were found to have a marked effect upon yield. Of the fertilizers applied, ammonium sulphate, superphosphate, and potassium sulphate (250 pounds each) gave the highest yield. From 10 to 15 tons of well-rotted manure should be applied per acre immediately after the first plowing, being thoroughly worked into the soil by disking. This will not only furnish plant food for the growing crop, but will also greatly improve the texture of the generally compact and heavy soils of Hawaii.

ROTATION

Edible canna is well adapted to either long or short rotation periods. It is recommended, however, that the crop be treated as an 8-months' crop, although harvesting may be delayed for several months longer without seriously affecting either yield or quality. The crops recommended for rotation are (1) corn, followed by edible canna, peanuts, and cowpeas (plowed under); (2) alfalfa (2 or 3 years), followed by corn, cassava, pigeon peas (plowed under), and edible canna; and (3) beans, followed by corn, edible canna, peanuts, cowpeas, and sweet potatoes. It is important that the land be freed from nut grass, which is not only extremely aggressive but also very hard to combat in a stand of this plant.

IRRIGATION

The plant resists drought reasonably well, and will stand a great deal of moisture when the area on which it is grown is well-drained. Whenever the rainfall is insufficient to meet the full water requirements of the crop irrigation should be practiced, the ground being thoroughly soaked twice a month. One heavy irrigation is worth several light irrigations.

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[4] Hawaii Sta. Rpt. 1918, p. 48.

HARVESTING

Edible canna has no definite period for maturing. In Queensland, its growth is checked in late fall by the frosts, and the plant begins to die back at any time during the next few months. In the Hawaiian Islands, where frosts do not occur, the plant continues to grow indefinitely, and it is difficult to determine the time tubers should be harvested to obtain the maximum yield. If grown for stock feed, the crop need not be removed from the ground until it is wanted for use. No labor-saving devices for harvesting edible canna have been invented or adapted to Hawaiian conditions. The stalks are cut down with a cane knife or other sharp instrument, and the entire stool is dug up with a spading fork or mattock. In some instances a plow is successfully used to loosen up the soil adjoining the hills or stools. As soon as the tubers are dug the roots and adhering earth should be removed. If the crop is wanted for stock feed, the tubers can be held for several weeks without injury. Tubers which are to be used for starch production should be taken to the mill immediately after digging in order that exposure may have no deteriorating effect on the quality of the manufactured product.[5]

YIELD

Yields vary with the rainfall and soil of the different regions in which the crop is grown. At the Glenwood substation, 7 tons of tubers were obtained with a 9-months' growing season.[6] At the Castner substation, 28 tons of tubers were obtained in 12 months from a soil to which manure was applied. A year later, yields ranging from 18 to 23 tons were obtained in the same locality.[7] At Waimea, Hawaii, it is reported that 40 to 50 pounds of tubers have been obtained in single hills of edible canna. The first trial planting at the station (Honolulu) yielded at the rate of 43 tons of tubers per acre in 24½ months after planting.[8] Subsequent tests gave results varying from 10 tons of tubers within 4 months after planting to 34 tons within 12 months after planting, with an average yield ranging from 18 to 20 tons per acre for 8-month periods.

KEEPING QUALITIES

One of the important features of the plant is the excellent keeping qualities of its tubers. Original seed tubers have been known to remain in excellent condition when left unharvested in the ground for a year or more. The tubers may be harvested and kept from decay for seed purposes for at least three months provided that they are cleansed of adhering soil and are thoroughly dried before being put in storage. The storage place should be kept cool and dark. The tubers may be piled in heaps not over 2 feet high. Higher stacking prevents proper circulation of the air and may result in the tubers decaying. The tubers may be stored in the field for a short time if the weather is dry. Results of experiments conducted at the station would seem to indicate that tubers can be

[5] Queensland Agr. Jour., v. X, Pt. I, p. 36, Tropical industries: Arrowroot, its cultivation and manufacture.
[6] Hawaii Sta. Rpt. 1919, p. 71.
[7] Hawaii Sta. Rpt. 1919, p. 47.
[8] Hawaii Sta. Rpt. 1917, p. 51.

kept in the field in good condition for one month when they are stacked in heaps not over 2 feet high and are covered with canna tops. In two months' time, the tubers that are nearest the ground will have started to germinate.

INSECTS AND DISEASES

This plant is remarkably free from both insect pests and plant diseases. Grasshoppers and Japanese beetles are occasionally found feeding on the foliage when more desirable host plants are not available, but their damage is negligible. In Waimea, Hawaii, cutworms are the most destructive pests of canna. Their injuries in certain seasons are confined to the tender young shoots which are either devoured or completely cut off at the base of the growing plant. The following poison baits are recommended as control measures:

Paris-green-bran mash.—Thoroughly mix 25 pounds of bran with one-half pound of Paris green. Add to the mixture 6 finely chopped lemons or 1 quart of cheap molasses. Stir well, and add sufficient water to moisten. Do not make the mixture so thin that it can not be easily and economically distributed.

Small patches should be treated with 1 ounce of Paris green to 3 pounds of bran, and one-half cup of molasses. Four to six times as much by weight of arsenate of lead should be used as in case of the Paris green, and only half as much white arsenic.

Poisoned succulent foliage.—Fresh cut alfalfa or other succulent foliage which is attractive to the insects may be sprayed with Paris green or arsenate of lead mixtures, and the poisoned leaves and stems scattered in the infested fields.

Criddle mixture.—Large areas may be treated with fresh horse dung, salt, and Paris green, in the proportions of 60, 2, and 1 pounds, respectively, per acre. This mixture is equally as effective and not as expensive as bran. The Paris green should be stirred into enough water to form a thin paste and then thoroughly mixed with the manure. Five pounds of arsenate of lead, or one-half pound of white arsenic, may be used instead of the Paris green.

Rats, which occasionally gnaw young tubers, can be brought under control by the use of traps and poisoned bait.

A field of canna will sometimes present a burned appearance in the dry season, due to the drying effect of hot winds.

COMPOSITION

In two analyses made at the station, edible canna was found to vary in water content from 65.86 to 81.58 per cent, and in nitrogen-free extract from 15.57 to 31.34 per cent.[9] The other constituents showed corresponding differences when expressed as percentages of dry material.

In making a study of the value of the crop as a feed and as a commercial source of starch, it is obviously necessary that determination be made of its average chemical composition and of the variations which take place. This is particularly important in case of the edible canna, which has no regular period for maturing and continues to grow indefinitely. On this account there has been a great difference of opinion as to the best age at which to harvest the tubers for maximum starch production. In some cases the crop is harvested after a growing period of 6 months, while in others it is allowed to grow for 18 months or more. Crops which differ so greatly in age would probably have appreciable differences in composition.

[9] Hawaii Sta. Press Bul. 53, p. 9.

VARIATION IN COMPOSITION OF THE TUBERS

In order to determine what progressive changes take place in the composition of the tubers, samples for analysis were harvested each month from a field at the station, beginning with the sixth month after planting and continuing through the twelfth month. Only one sample was analyzed during each of the first three months. As the work progressed it became apparent that, due to the short life cycle of the canna, the variations in the composition of tubers within a single hill were greater at any time than they were between composite samples that were harvested a month apart. In order to determine the monthly variations of the entire hill and the individual differences taking place within the hill, the tubers harvested during the last three months were divided into three groups having the following characteristics:

(1) Old tubers (cylindrical to oval in shape). The tops of the tubers were dead. The gradual tapering of the tuber, as compared with tubers in group 2, shows that in the late stage of growth starch is stored in the lower two or three inches of the stalk, which then, for starch manufacture, becomes an integral part of the tuber.

(2) Mature tubers (oval to round in shape). The plants had reached the bloom stage. The tubers were mature and had attained their maximum diameter.

(3) Immature tubers (round in shape). The tops of the plants were either just above ground or had not as yet emerged. The tubers were of course smaller than in case of either of the preceding groups.

Roots, dead scales, and adhering soil were all removed from the tubers as soon as they were dug. After being weighed, shredded, and dried, the tubers were analyzed by the methods recommended by the Association of Official Agricultural Chemists.[10]

Chemical analyses of the tubers, which were harvested monthly, are given in the following table:

Effect of stage of maturity of harvesting on the percentage composition of edible canna tubers [a]

Age	Water	Protein	Fat	Carbohydrates		Ash
				Nitrogen-free extract	Crude fiber	
Fresh material	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Six months	80.58	0.94	0.07	16.72	0.40	1.29
Seven months	77.53	.71	.08	19.95	.39	1.34
Eight months	76.09	.56	.09	21.62	.40	1.24
Nine months:						
Mature [b]	70.10	.77	.10	27.10	.67	1.26
Immature	77.26	.94	.08	19.74	.51	1.47
Average	73.68	.86	.09	23.42	.59	1.36
Ten months:						
Old	72.49	.79	.12	24.41	.79	1.40
Mature	68.78	1.01	.12	28.25	.51	1.33
Immature	76.18	1.25	.11	20.44	.48	1.54
Average	72.48	1.02	.12	24.37	.59	1.42

[a] The results are given on the oven-dry weight as well as on the fresh material because the former brings out more clearly the variations in the composition of the different groups of tubers.

[b] Sample includes both old and mature tubers.

[10] Methods of analysis of the Association of Official Agricultural Chemists, sec. VII, p. 71–99. Revised to Nov. 1, 1919, Washington, D. C., 1920.

Effect of stage of maturity of harvesting on the percentage composition of edible canna tubers—Continued

Age	Water	Protein	Fat	Carbohydrates		Ash
				Nitrogen-free extract	Crude fiber	
Fresh material—Continued						
Eleven months:	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Old	67	0.93	0.12	29.65	0.88	1.42
Mature	66.77	1.07	6.12	30.06	0.55	1.43
Immature	70.25	1.00	.13	26.49	.61	1.52
Average	68.01	1.00	.12	28.73	.68	1.46
Twelve months:						
Old	71.92	.87	.10	25.18	.73	1.20
Mature	75.41	1.01	.09	21.5	.51	1.48
Immature	81.68	1.2	.07	15.09	.57	1.39
Average	76.33	1.03	.09	20.59	.60	1.36
Oven-dried material						
Six months		4.83	.36	86.08	2.08	6.65
Seven months		3.14	.34	88.8	1.75	5.97
Eight months		2.33	.37	90.43	1.69	5.18
Nine months:						
Mature [b]		2.58	.35	90.6	2.25	4.22
Immature		4.13	.34	86.8	2.27	6.46
Average		3.36	.34	88.7	2.26	5.34
Ten months:						
Old		2.87	.43	88.76	2.86	5.08
Mature		3.21	.39	90.51	1.64	4.25
Immature		5.23	.44	85.86	2.02	6.45
Average		3.77	.42	88.38	2.17	5.26
Eleven months:						
Old		2.8	.37	89.85	2.67	4.31
Mature		3.21	.35	90.51	1.64	4.29
Immature		3.34	.44	89.06	2.04	5.12
Average		3.12	.39	89.8	2.12	4.57
Twelve months:						
Old		3.09	.35	89.71	2.58	4.27
Mature		4.15	.35	87.42	2.07	6.01
Immature		6.61	.38	82.33	3.1	7.58
Average		4.62	.36	86.49	2.58	5.95

[b] Sample includes both old and mature tubers.

The transition from immaturity to maturity and thence to post-maturity is a very gradual one, and it is impossible to select from monthly harvests tubers that have reached the same stage of maturity, because of the short life cycle of the plant. Obviously, some of the variations given in the preceding table are due to faulty sampling.

In general, however, the above data show that, with respect to variations among the three groups of tubers, the moisture content is always the greatest in the immature tubers. Apparently it decreases until the tubers reach the mature stage, after which it remains fairly constant. In several instances there are slight increases in the moisture content of the old tubers over the mature ones.

Expressed as percentages of dry weight, the protein and ash show a considerable decrease in the transition of the tubers from immaturity to maturity, while the crude fiber of the mature tubers is in each instance less than in case of the old tubers. The nitrogen-free

extract is always lowest during immaturity, while in two out of three instances it is higher during maturity than in the older stages.

A comparison of the average composition by months shows no consistent variations other than a gradual decrease in the moisture content up to the twelfth month. This is to be expected because the ages of the mature and immature tubers of the several months are about the same regardless of the month of harvest. Since the tubers vary little in composition after they reach the mature stage, the hill as a whole should show little variation in composition from month to month.

The twelfth-month samples show an abrupt change in composition as compared with samples of the preceding months. The water content made an average increase of more than 8 per cent, whereas it showed a continuous decrease in the preceding months. Coupled with the high protein and ash content of the immature groups, this change is indicative of new and quick growth. That such was the case is shown by the fact that at 11 months from planting, 21 hills of canna contained 397 immature tubers and a total yield of 183 pounds, while at 12 months from planting, a like number of hills contained 671 immature tubers and a total yield of 303.5 pounds. Unfortunately, this field was plowed before a further study could be made. It is highly probable, however, that with the return of normal weather conditions the average composition of the hill eventually would have become the same as it had been in the period preceding the twelfth month.

In brief, it may be concluded that after an individual tuber has reached maturity, which requires from 30 to 90 days, it varies little in composition at least for a year, except for an appreciable increase in fiber content; and provided that weather conditions remain constant, the composition of the hill as a whole changes little. Consequently, the crop will have practically the same composition regardless of the age at which it is harvested. The best age at which to harvest may therefore be decided largely by the yields obtained. The analyses as given in the preceding table show the following to be the average composition of edible canna tubers:

Chemical composition of edible canna

Constituent	Fresh material	Oven-dried material	Constituent	Fresh material	Oven-dried material
	Per cent	*Per cent*		*Per cent*	*Per cent*
Water	72.62		Nitrogen-free extract	24.28	88.68
Protein	.98	3.58	Crude fiber	.61	2.23
Fat (ether extract)	.11	.40	Ash	1.40	5.11

VARIATION IN COMPOSITION OF THE TOPS

Since canna tops may attain maximum growth in as short a time as 30 days under proper climatic conditions, it would seem as though rapid changes in composition must take place. To permit of a study of such changes, the tops of a hill 12 months old were divided into three stages of growth: (1) Old stage, in which the blooms were dead and the lower leaves were beginning to wither; (2) bloom stage; and (3) immature stage averaging 2 feet in height. The following table shows the effect of the stage of maturity on the composition of canna tops.

Effect of stage of maturity on the percentage composition of canna tops

Stage of maturity	Water	Protein	Fat	Carbohydrates		Ash	Nutritive ratio
				Nitrogen-free extract	Fiber		
Fresh material	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	
Old tops	88.67	1.07	0.33	5.83	2.77	1.33	1 : 6.14
Mature tops	89.39	1.13	.23	5.32	2.46	1.47	1 : 5.17
Immature tops	92.47	1.12	.14	3.20	1.70	1.37	1 : 3.14
Average	90.18	1.11	.23	4.78	2.31	1.39	1 : 4.81
Oven-dried material							
Old tops		9.47	2.95	51.40	24.45	11.73	
Mature tops		10.68	2.14	50.15	23.15	13.88	
Immature tops		14.94	1.91	42.44	22.50	18.21	
Average		11.70	2.33	48.00	23.37	14.60	

The above table shows that all the samples analyzed contained a high percentage of moisture which decreased with increasing maturity; and, likewise, that the percentage of fat, nitrogen-free extract, and fiber increased, while the ash and protein decreased, with increasing maturity. The nutritive ratio of the old tops was 100 per cent wider than in case of the immature group.

COMPOSITION OF EDIBLE CANNA GROWN IN WAIMEA

Waimea, Hawaii, gives promise of becoming an important canna-producing region. In this district, where the system of farming resembles the grain and stock farms of the Mississippi Valley, the repeated failure of most of the staple crops has forced homesteaders to cultivate some crop which can be depended upon as a source of feed. Edible canna has shown itself to be especially well adapted to the high altitude and high winds of the region, and could be utilized both as a stock feed and as a commercial source of starch. It grows luxuriantly notwithstanding such adverse conditions as high winds, low temperature, and drought. With the return of favorable conditions new buds develop and growth proceeds without the stunting effect so manifest in most other crops. The soil at Waimea is ideal for canna culture, being of a porous nature, in striking contrast with most of the easily compacted soils of the islands.

Three samples of canna were obtained from Waimea for analysis, one consisting of very old tubers, and the other two corresponding to the mature and immature types described on page 8. The old tubers had been in the ground for over two years and gave no evidence of decay except for a slight darkening of the tissue. The surfaces bore deep cracks, which, however, had healed without decay. The tops of the new growth had been repeatedly cut for feed, leaving the tubers partly exposed. The following table shows the effect of stage of maturity on the composition of canna tubers which were grown in Waimea.

Effect of stage of maturity on the percentage composition of edible canna grown at Waimea

Stage of maturity	Water	Protein	Fat	Carbohydrates		Ash
				Nitrogen-free extract	Crude fiber	
Fresh material	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Old	75.85	0.66	0.10	21.59	0.69	1.11
Mature	74.68	1.41	.11	22.19	.53	1,08
Immature	82.63	1.17	.07	14.43	.52	1.18
Average	77.72	1.08	.09	19.40	.58	1.13
Oven-dried material						
Old		2.72	.41	89.43	2.86	4.58
Mature		5.56	.44	87.66	2.08	4.26
Immature		6.76	.40	83.05	2.98	6.81
Average		5.01	.42	86.71	2.64	5.22

In general, the above table shows that canna from Waimea has the same composition as that grown at the central station. It also shows similar variations in composition among the three types of tubers. As a result of remaining in the soil for two years, the old tubers showed a smaller proportion of protein, but a slightly larger proportion of water, than did the mature tubers.

FEEDING VALUE

At the present time both tubers and tops are used largely as stock feed. The tubers may be fed raw, but are usually shredded and cooked first. Goff [11] reported that the tops were fed by hog raisers on Hawaii with no other preparation than cutting them into 6-inch lengths. When fed with soured rice bran, the tops caused the animals to gain steadily in weight.

Although the station has conducted no extensive feeding tests with canna tops for horses and mules, its four work mules have been observed to eat them readily and sometimes to leave their grain for the tops.

The following table compares the composition and feeding value of edible canna and other forage and starch crops:

Comparison of the percentage composition and feeding value of edible canna and other starch and forage crops

Crop	Part of plant	Water	Protein	Fat	Carbohydrates		Ash	Nutritive ratio
					Nitrogen-free extract	Crude fiber		
		Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	
Edible canna	Tubers	72.62	0.98	0.11	24.28	0.61	1.40	1:25.0
	Tops	90.18	1.11	.23	4.78	2.31	1.39	1:4.8
Taro [a]	Tubers	60.55	1.10	.13	36.91	.58	.73	1:33.8
	Tops	84.56	1.86	.49	10.29	1.42	1.38	1:6.1
Sweet potato [a]	Tubers	68.89	2.12	1.26	27.02	.81	.90	1:14.1
	Tops	87.67	2.93	.36	6.08	1.69	1.27	1:2.4
Cassava [a]	Tubers	64.17	.77	1.59	31.42	1.19	.86	1:45.4
Potato [b]	Tubers	78.30	2.20	.10	18.00	.40	1.00	1:8.3
Napier grass [c]		61.81	2.92	.29	17.29	14.77	2.92	1:6.1
Para grass [d]		74.60	2.28	.29	10.92	9.10	2.81	1:5.1

[a] Hawaii Sta. Press Bul. No. 53, pp. 8, 9, and 10: Composition and digestibility of feeding stuffs grown in Hawaii.

[b] U. S. Dept. Agr., Office of Experiment Station Bul. No. 28 (revised), p. 68. The chemical composition of American food materials.

[c] Philippine Islands Jour. Prog. Agr., v. IV, no. 9, p. 27: Napier grass.

[d] Hawaii Sta. Bul. No. 13, p. 8: The composition of some Hawaiian feeding stuffs.

[11] Hawaii Sta. Rpt. 1919, p. 71.

FIG. 1.—EDIBLE CANNA STARCH. MAGNIFIED 220 DIAMETERS.

FIG. 2.—POTATO STARCH. MAGNIFIED 220 DIAMETERS.

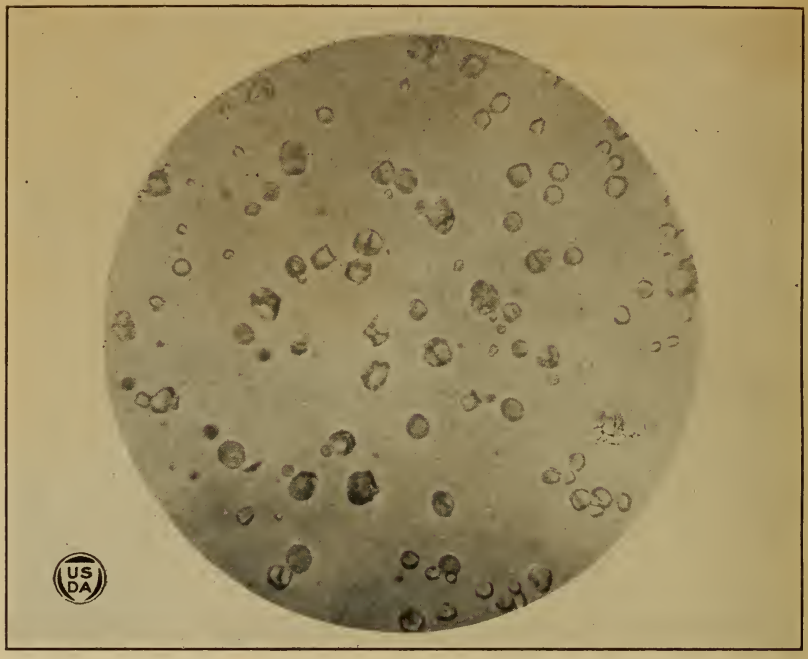

FIG. 1.—CORN STARCH. MAGNIFIED 220 DIAMETERS.

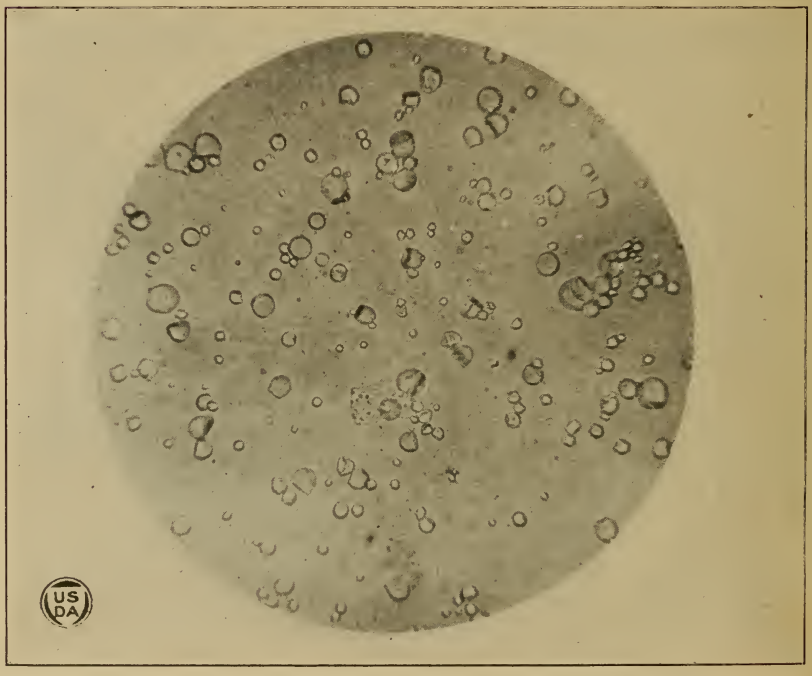

FIG. 2.—CASSAVA STARCH. MAGNIFIED 220 DIAMETERS.

The table on page 12 shows that edible canna tubers have about the same feeding value as other tuberous crops possessing a nutritive ratio that is narrower than that of cassava or taro, and wider than that of potatoes or sweet potatoes. As a forage crop, the tops compare favorably with other crops. They are succulent and have a comparatively narrow nutritive ratio. Compared with the grasses, they are lower in crude fiber and higher in protein, calculated on a dry-weight basis. Low and high protein are both advantageous.

EDIBLE CANNA STARCH

Chemically, all starches are alike, being the condensation product of dextrose and having the general formula $(C_6H_{10}0_5)n$. In this formula, however, "n" varies between wide limits, ranging from about 30 to 200 or more. The value of "n" and the space arrangement within the starch granule are subject to great variation and give rise to striking physical differences. When determining the character of a starch, it is necessary, therefore, to study only its physical properties.

IDENTIFICATION

Morphologically, edible canna starch is characterized by its exceptionally large granules. (Pl. I, fig. 1.) Its identifying characteristics are as follows: Shape, irregular, ovoid; hilum, eccentric and annular; rings, plainly visible; length, 0.04 to 0.13 millimeters; with polarizer, well defined cross at hilum is visible both with and without selenite plates.

Edible canna starch and potato starch are somewhat alike in appearance, the chief difference being in the hilum, which is annular and not so prominent in canna starch, and occurs as a spot in potato starch. In the latter the small grains are almost round, with the hilum central. In the potato starch both large and small granules occur in about equal proportion (Pl. I, fig. 2), whereas, in the canna starch the large ones greatly predominate. For purposes of comparison the starches of corn and cassava are shown in Plate II, figures 1 and 2.

VISCOSITY

When a starch is heated in water to a temperature that is sufficiently high to break the granules it becomes colloidal in nature. The viscosity of this so-called "soluble starch" is to some extent a measure of its value for certain uses, as for example, in the textile industry.

The viscosity of colloidal starch can be made to vary between wide limits. The time and method of cooking, the temperature, and the concentration greatly affect the total viscosity. If the solution is vigorously shaken while it is hot the viscosity can be reduced to as little as one-half of its value without such agitation. The viscosity increases with decreasing temperature and the starch hydrogel changes to a definite hydrogel if the solution is sufficiently concentrated. Different samples of starch from the same source often show pronounced differences in viscosity.

Apparently, therefore, certain arbitrary conditions must be conformed to when the viscosity of a starch is measured. The viscosity thus observed holds true only for these conditions. The method of procedure adopted for this study was as follows: Varying amounts of starch were weighed into 100 cubic centimeter flasks graduated at 80° C., and shaken with 10 cubic centimeters of cold water. Boiling water was then added with vigorous shaking and the flask made up to the mark at 80° C. with hot water. After thorough mixing they were placed in boiling water for one hour without agitation. They were then quickly cooled to 80° C. with as little agitation as possible and the viscosity determined at this temperature by means of a Saybolt standard viscosimeter. Results can be duplicated with fair accuracy at 80° C. but will vary widely, probably due to the tendency of the colloid to form a plastic gel, if the solution is cooled to room temperature.

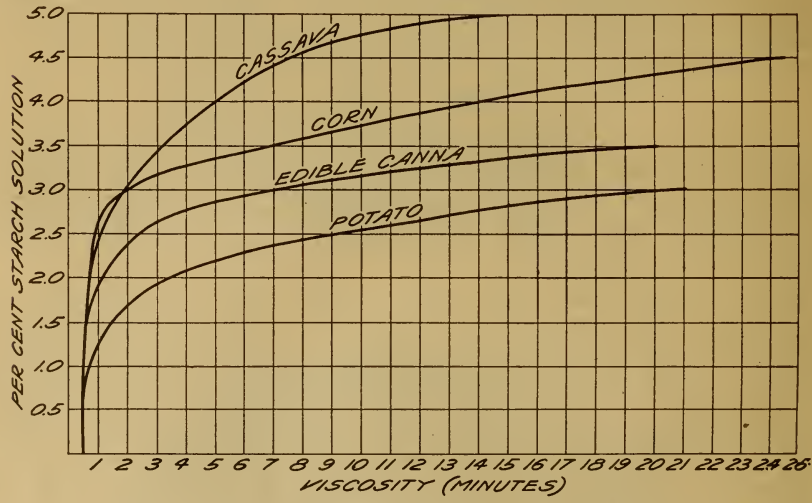

FIG. 4.—Comparison of the viscosities of various solutions of edible canna starch, potato starch, corn starch, and cassava starch.

The Saybolt universal viscosimeter is essentially a cylindrical tube having a diameter of 3 centimeters, a height of 10 centimeters, and a capacity of 70 cubic centimeters. The bottom of the tube is constricted to an opening 1.77 millimeters in diameter. The tube is surrounded by a water or oil bath so that any desired temperature can be maintained. The viscosity is determined by filling the tube with the solution to be tested, and noting the time necessary to fill a flask of exactly 60 cubic centimeters capacity through the opening in the bottom of the tube. This type of viscosimeter is probably not so well adapted for the measurement of the viscosity of starches as is the torsion viscosimeter, which would have less destructive effect on the easily affected structure of the starch solution.

A comparison of the viscosities of various solutions of edible canna starch, potato starch, corn starch, and cassava starch are given in the following table, and also graphically in Figure 4.

Comparison of viscosity of edible canna starch and other starches

Starch solution	Viscosity (Saybolt) at 80° C [1]							
	Edible canna		Potato		Corn		Cassava	
Per cent	*Min.*	*Sec.*	*Min.*	*Sec.*	*Min.*	*Sec.*	*Min.*	*Sec.*
0.5	---	31	---	33	---	30	---	28
1.0	---	33	---	41	---	32	---	32
1.5	---	38	1	29	---	36	---	35
2.0	1	10	3	24	---	42	---	48
2.5	2	19	9	---	---	54	1	--
3.0	7	15	21	---	1	35	1	46
3.5	20	15	---	---	6	45	3	13
4.0	---	---	---	---	13	40	4	57
4.5	---	---	---	---	24	32	7	27

[1] Twenty-eight seconds are required to run 60 cubic centimeters of distilled water at 80° C. through the viscosimeter.

From the above table it is apparent that potato starch possesses a greater viscosity than do either of the other two starches. Canna starch is, however, greatly superior to either corn starch or cassava starch in this respect. It was observed that the viscosity of potato starch is reduced by agitation more easily than is that of canna starch. This is true, especially in concentrations of about 2 per cent, where the viscosity begins to rise abruptly with small increments of starch.

GELLING STRENGTH

Hot starch solutions, which were prepared like those used in the viscosity tests, were poured into test tubes one-half inch in diameter and allowed to cool for one hour. The tubes were then inverted. The minimum concentration necessary to keep the mass from running down the side of the inverted tube was termed its "gelling strength."

The gelling strength of edible canna starch, potato starch, corn starch, and cassava starch was found to be 3.75, 3.25, 4, and 6.25 per cent, respectively. Examinations of the four starches at the concentrations noted above showed, however, that while the corn starch and the cassava starch formed a definite gel structure, which retained its shape when shaken out of the tube, the other two starches remained as hydrosols or possibly as plastic gels having sufficiently high viscosity to prevent their running down the side of the tube.

USES

Both the foliage and the tubers of the edible canna make excellent feed for dairy cows, and the tubers when cooked are fairly good for pigs. The small, immature tubers when cooked resemble white potatoes in taste and consistency, but soon become too fibrous to be palatable. The tubers are little used for human consumption in Hawaii.

The starch would seem to have considerable value as a food and for industrial uses. A very pure product can be prepared by simply shredding the tubers, mixing the pulp with water and passing the whole through a perforated screen, and finally, by separating the fecula or amylaceous matter from the fibrous substance by sedimentation. Owing to its extraordinarily large granules, the starch settles in a few minutes and very little time and expense is required to free

it from impurities. The starch has a glossy appearance, with a decided glisten in certain lights, in marked contrast with the smaller-grained starches which are of dull and amorphous appearance. When cooked it forms a semitranslucent, rather sticky mass, such as is characteristic of potato or arrowroot starch but different from the opaque gel obtained from corn starch. Since pure starches are tasteless, the flavor of the resultant product is, of course, the same regardless of the kind of starch used. The starch is often recommended for use for invalids and for infants, due to its large granules.

SUMMARY

Under Hawaiian conditions edible canna can be grown during any season of the year. It produces its maximum yield, however, when grown for a definite period at an altitude of less than 1,500 feet.

The crop is adapted to either long or short-rotation periods, and requires a loose, loamy, and well-drained soil for best development. Cultivation is essential when the crop is grown in a hard, compact soil.

Edible canna is free from attacks of injurious insects and plant diseases, and produces an average of 18 to 20 tons of tubers per acre. The tubers have excellent keeping qualities. Only vigorous tubers which bear unbruised buds should be selected for propagation.

The average composition of a hill of edible canna tubers varies little regardless of the period of growth. Weather changes stimulating new growth may cause temporary variation, however.

In an examination of immature, mature, and old tubers from a single hill, the immature tubers were found to differ considerably from the mature and old tubers, which were similar in composition.

Decided changes in the composition of the tops were observed to occur in the transition from immaturity to maturity, and thence to the older stages of growth. The nutritive ratio was nearly 100 per cent wider for the old than for the immature tops.

Canna grown at Waimea, Hawaii, had substantially the same composition as did that grown at the central station. Tubers which remained in the ground for two years showed a loss in protein content but otherwise were unchanged.

The feeding value of both the tubers and the tops compares favorably with that of other starch and forage crops.

Canna starch is characterized by its exceptionally large grains. Morphologically, it is similar to potato starch. Its viscosity is greater than that of corn starch but less than that of potato starch.

It is thought that edible canna starch has potential possibilities both as an edible starch and for commercial uses. It makes quick growth, produces heavy yields, and can be harvested at any age and during any season, and should therefore lend itself admirably to continuous production at minimum cost. When the crop is grown on a large scale, the tubers should be produced at a comparatively low cost per ton. The starch should be manufactured at exceptionally small cost since it is separated with ease. Although starch from edible canna was not produced in Hawaii for industrial purposes until 1922, there is no reason why it should not become as popular as potato starch, with which it is closely comparable.

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